Waseda University
Research Institute for Science and Engineering

Design of a Clean, High Brightness Light Source for EUV Lithography Research in Shorter Wavelength

Research Institute for Science and Engineering,

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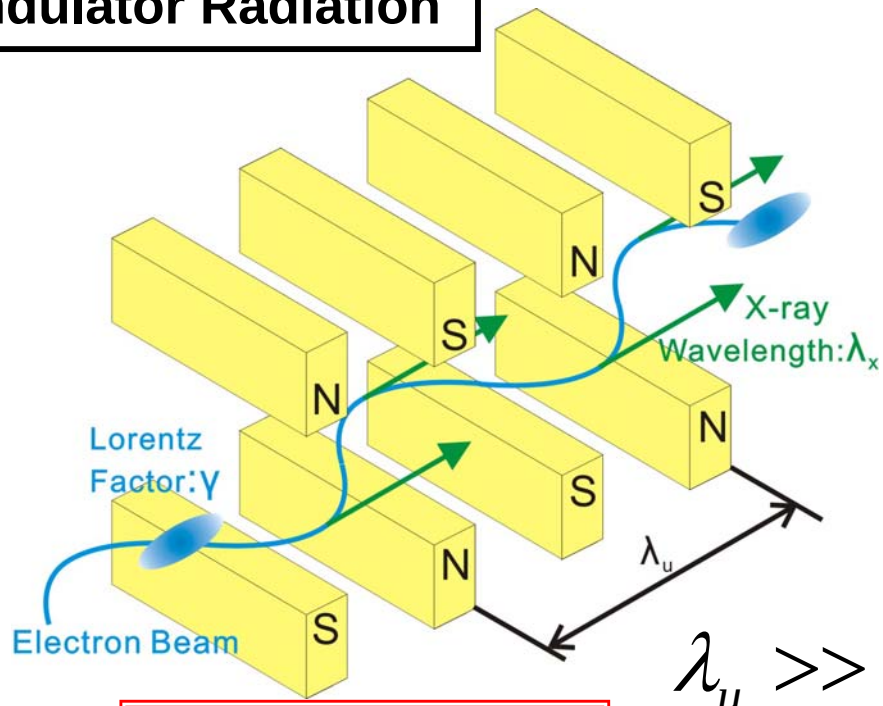
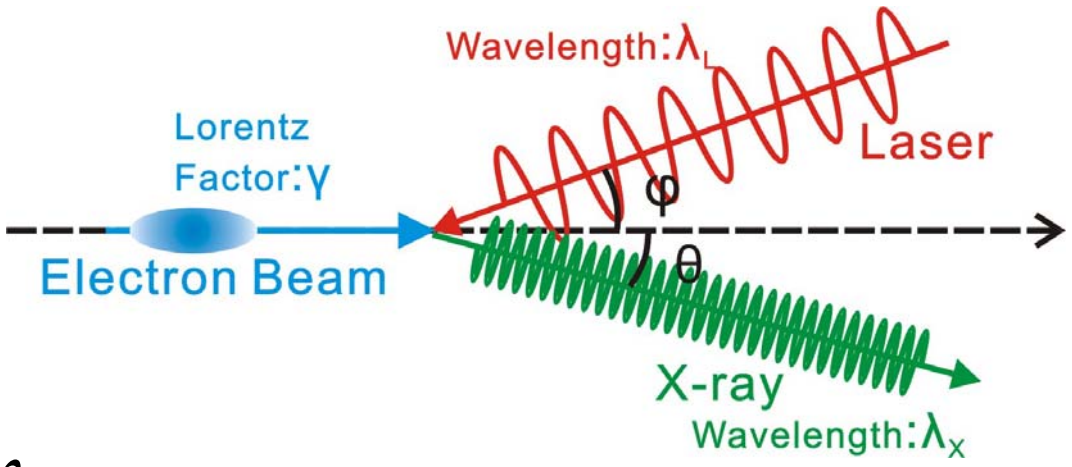
Laser Compton Scattering

Comparison of Undulator Radiation and Laser-Compton Scattering

Undulator Radiation



Laser-Compton Scattering



$$\lambda_u >> \lambda_L$$

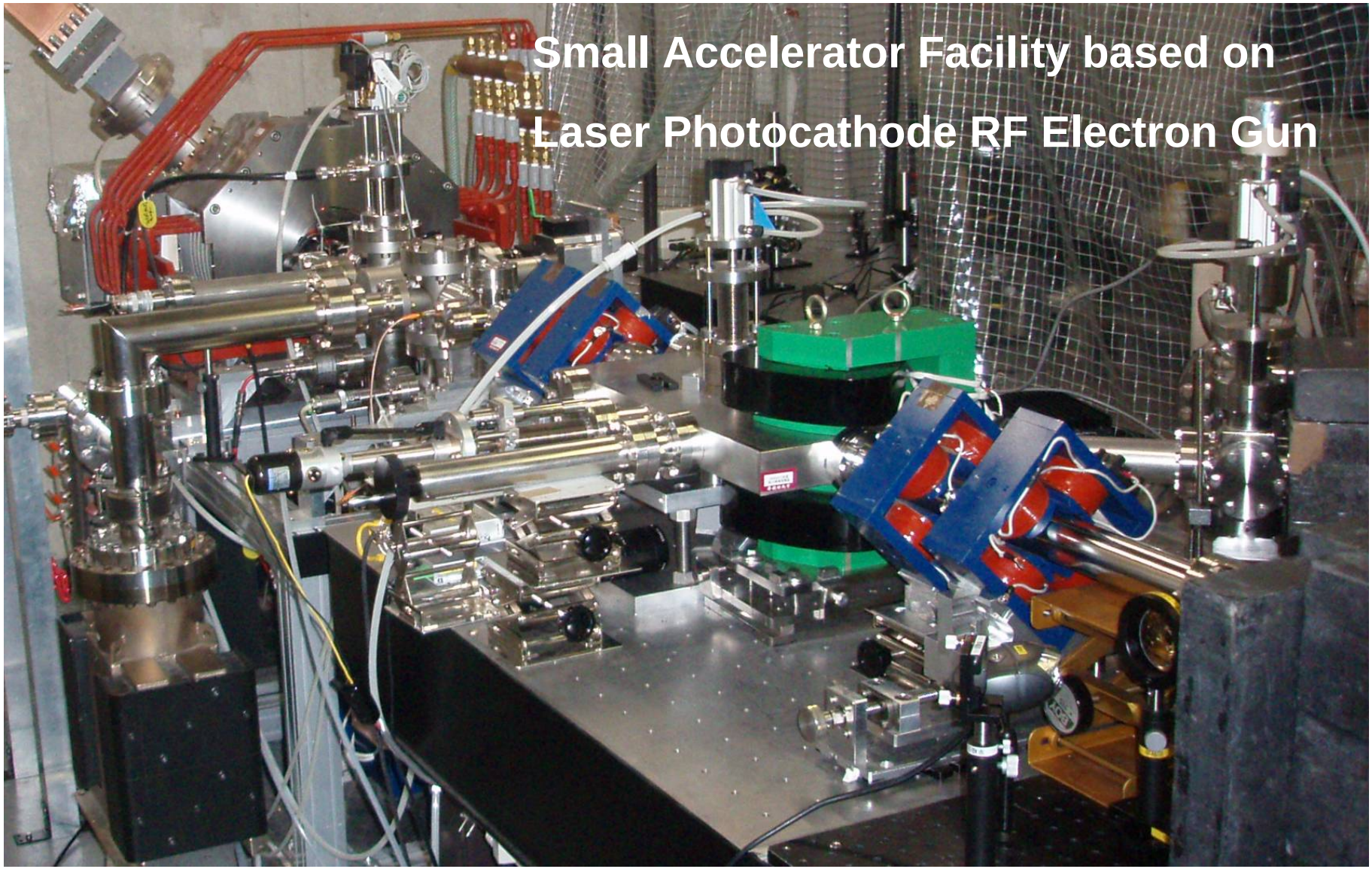
$$E_X = 2\gamma^2 \cdot hc/\lambda_u \quad \Leftrightarrow \quad E_X = 2\gamma^2 \cdot hc/(\lambda_L/(\cos\phi + 1/\beta))$$

Undulation period can be shortened over 3-order of magnitude

High energy photon is produced with small accelerator system

Soft X-ray Generation Experiment

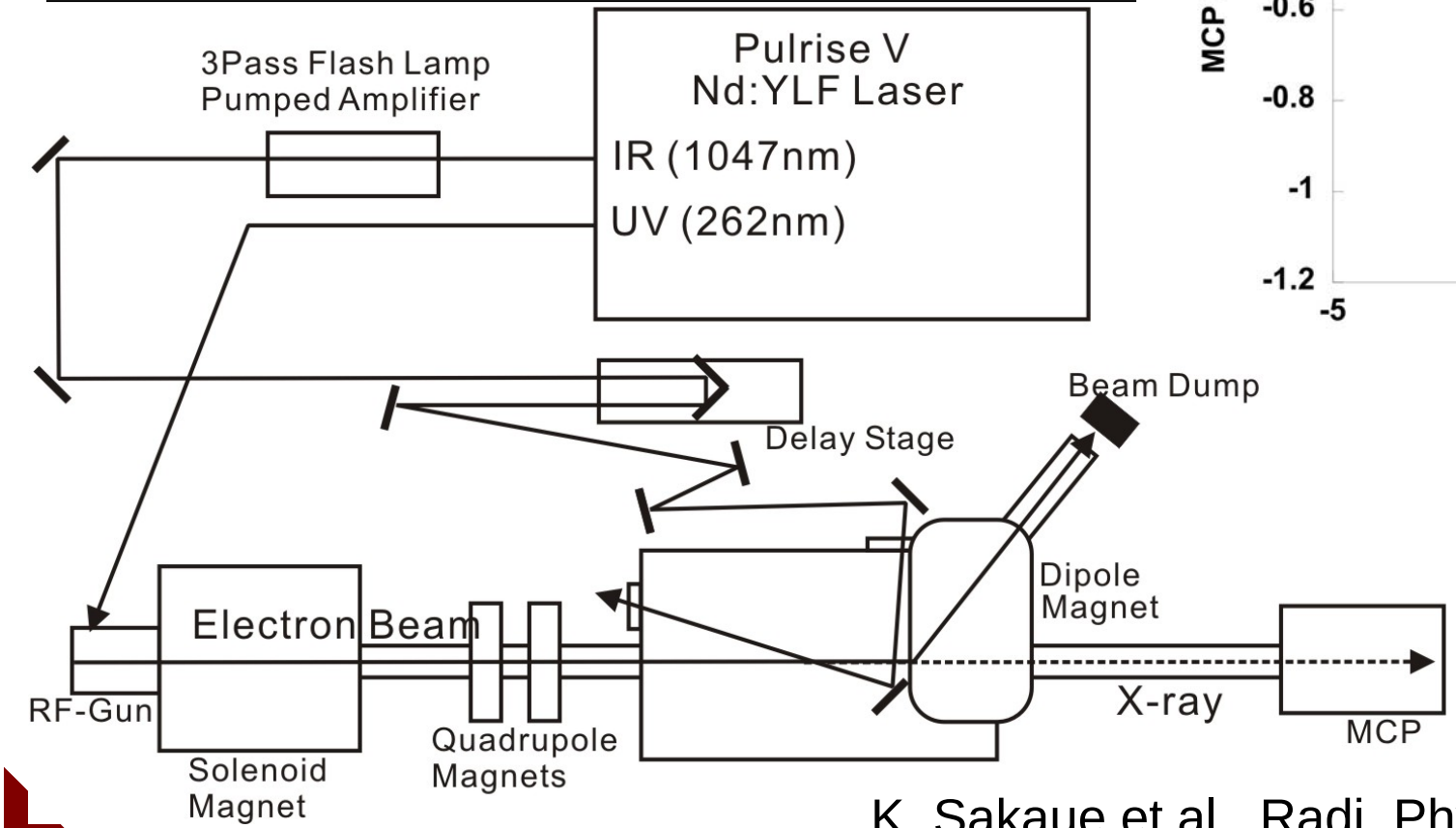
Facility Outlook at Waseda University

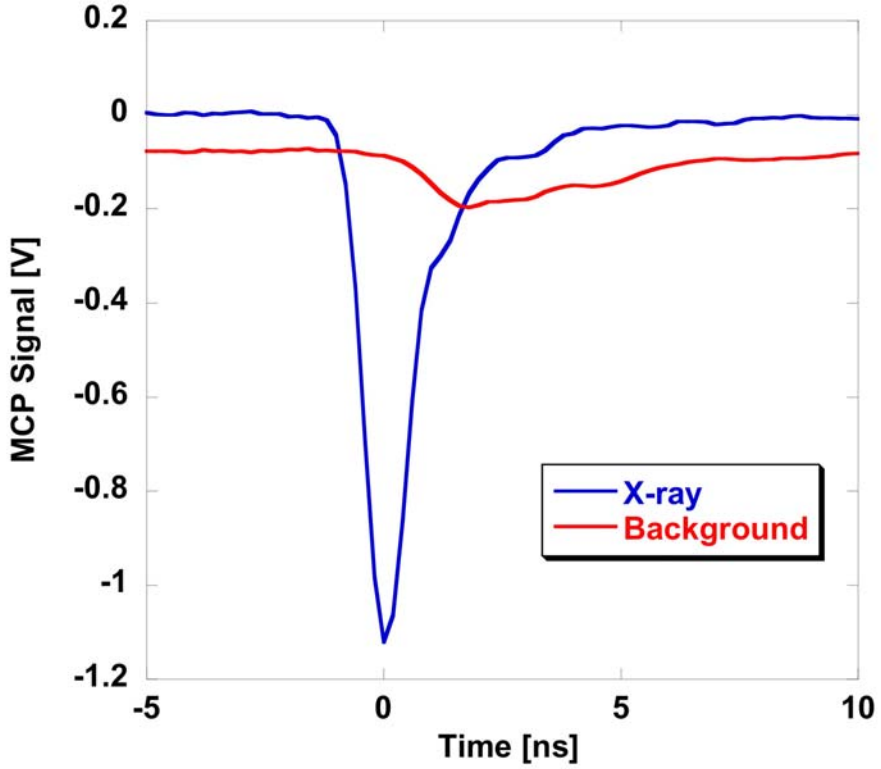


Soft X-ray Generation Experiment

Results of Soft X-ray Generation

Electron beam		Laser beam	
Energy	4.6 MeV	Wavelength	1047 nm
Bunch charge	350 pC	Pulse energy	36 mJ
Size (horizontal)	251 μm	Size (horizontal)	42 μm
Size (vertical)	56 μm	Size (vertical)	42 μm
Bunch length	10 ps (FWHM)	Pulse duration	10 ps (FWHM)



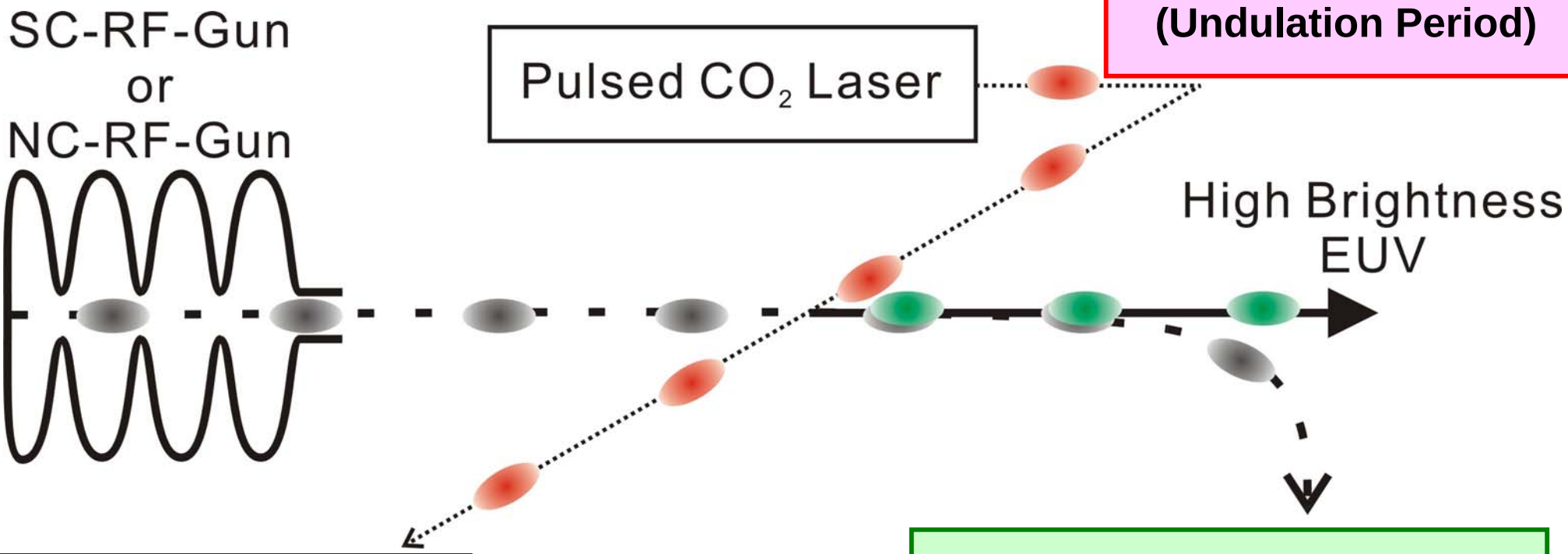


3.3×10^4Photons
were produced
in 1pulse
Ex~420eV (2.8nm)

K. Sakaue et al., Radi. Phys. Chem. 77(2008)1134

Design of EUV Light Source

Design of EUV Light Source based on Laser-Compton Scattering



Use CO_2 Laser for Longer Wavelength (Undulation Period)

RF-Gun can generate high brightness electron beam ~10.5MeV

Generated photon has around 6.7nm wavelength 7.2MeV electron & 10.6 μ m laser

Design of EUV Light Source

We have 2 case of designs

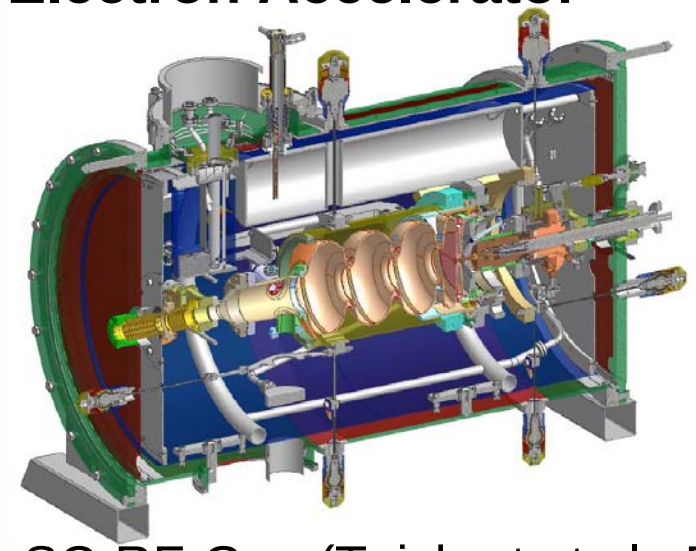
“Low Rep. Case (100kHz)” and “High Rep. Case (100MHz)”

	100kHz	100MHz	
Bunch charge	1nC/bunch	77pC/bunch	**Electron Beam**
Bunch length	3psec (rms)	3psec	
Pulse energy	1J/pulse	20 μ J/pulse	
Pulse duration	20nsec	20psec	**Laser**
Enhancement	None	5000	
Diameter	10 μ m	20 μ m	
Colliding angle	0deg	5deg	
EUV power	12.8 μ W/2%b	1mW/2%bw	**EUV**

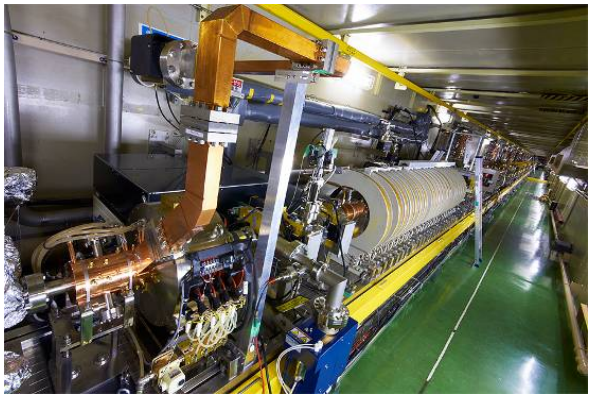
EUV Light Source (Low Rep. Case)

Components of Low Rep. Case

Electron Accelerator

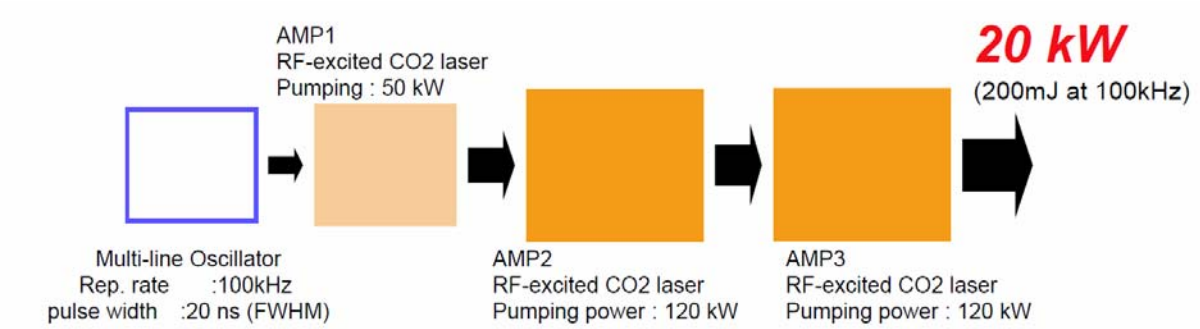


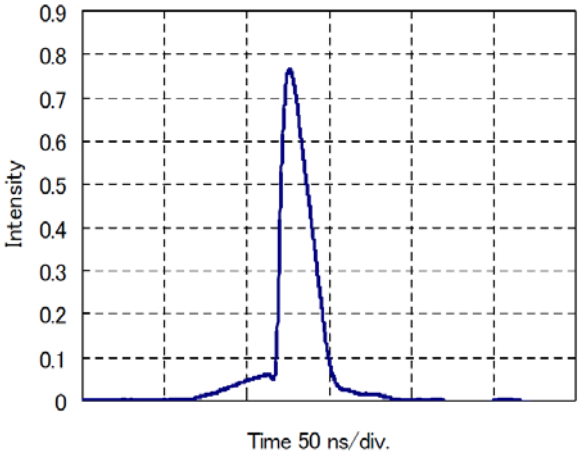
SC-RF-Gun (Teichert et al., FEL08)

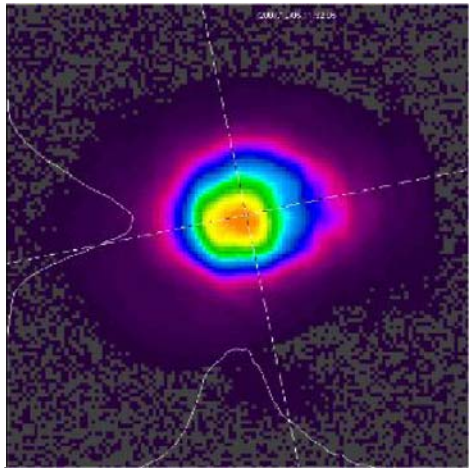


NC-RF-Gun (Now under testing at KEK)

CO_2 Laser







1J/pulse is also feasible technology

EUV Light Source (High Rep. Case)

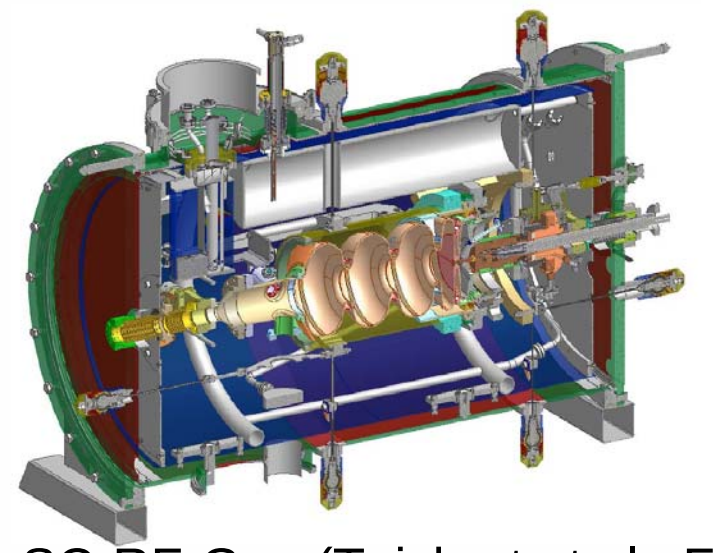
Components of High Rep. Case (Electron Beam)

>Almost same requirements with ERL (Energy Recovery Linac)

electron source

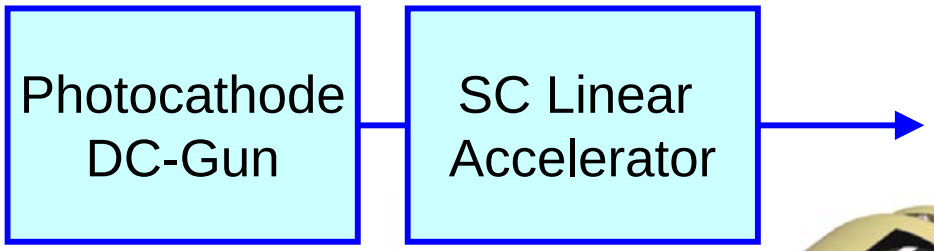
These will be mature in near future

SC-RF-Gun



SC-RF-Gun (Teichert et al., FEL08)

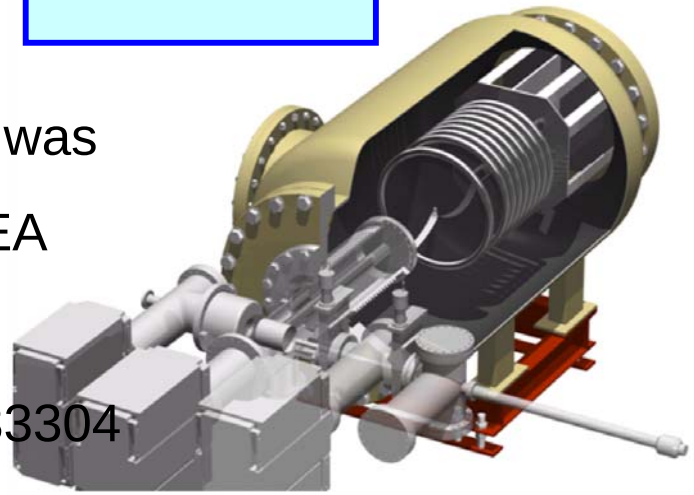
DC-Gun & SC Linac



500kV DC-Gun was achieved at JAEA

R. Nagai et al.,

RSI 81(2010)033304

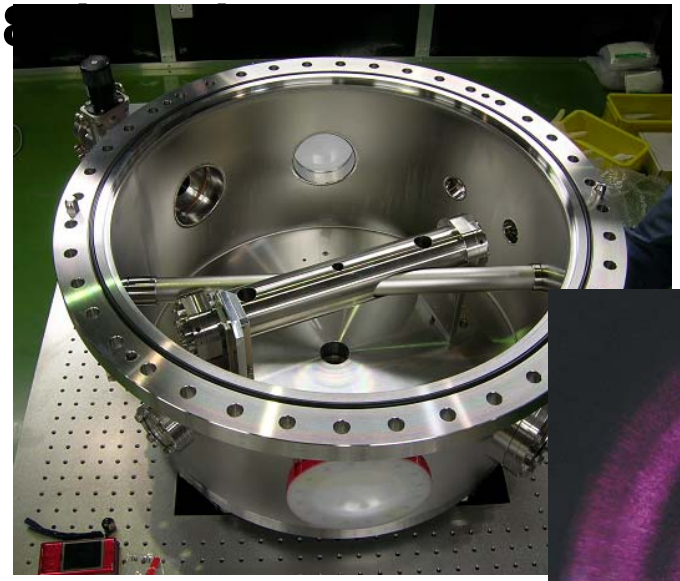


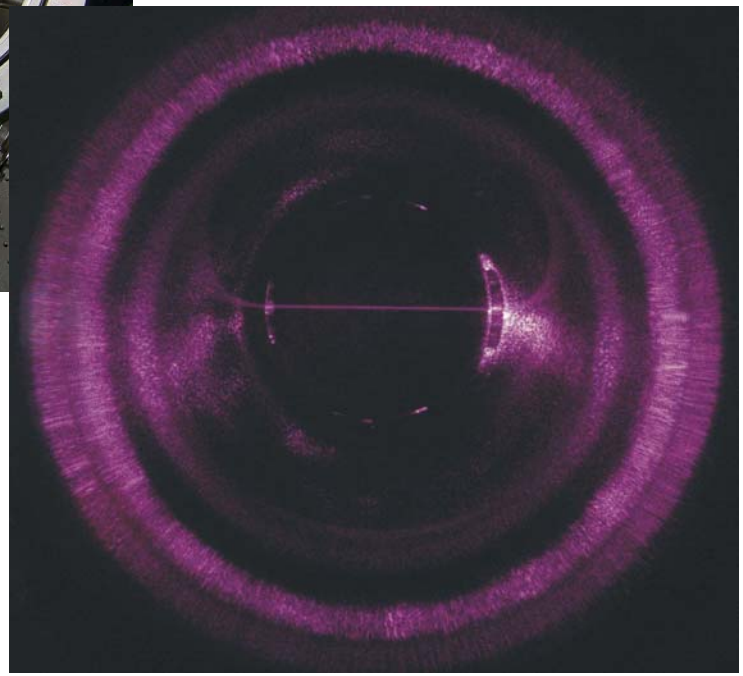
EUV Light Source (High Rep. Case)

Components of High Rep. Case (Laser Beam)

>Need to use Super-cavity technology

Demonstrated at 1 μ m wavelength K. Sakaue et al., RSI





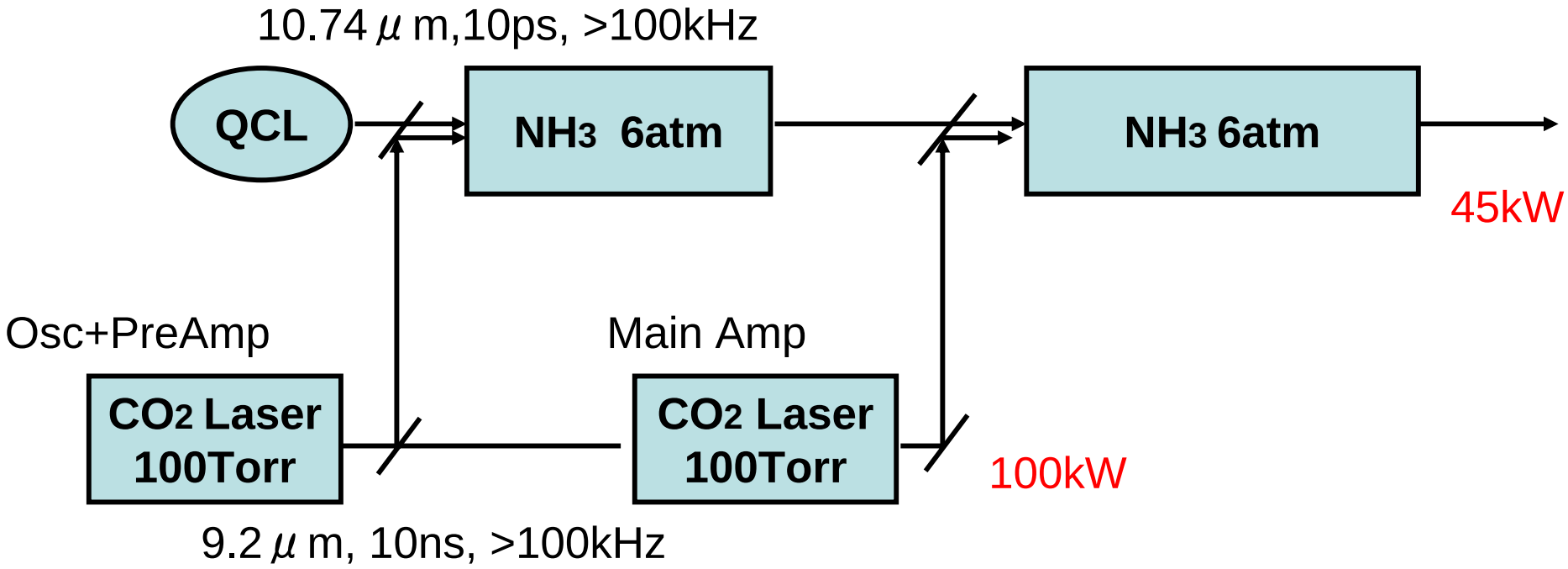
Need to R&D at 10.6 μ m CO_2 laser storage in optical super-cavity with enhancement of 5000

In our calculation, 600enhancement will be achieved with commercial mirrors

EUV Light Source (High Rep. Case)

Components of High Rep. Case (Laser Beam)

>Need to demonstrate high rep., short pulsed CO_2 laser



20psec pulsed CO2 laser will be achievable using optically pumped NH3
J. D. White et al., IEEE J. QE, 29(1993)201

Summary

We have been developing a laser-Compton scattering

Soft X-ray was demonstrated by 4.6MeV electron and 1um laser

Under our experiences of laser-Compton scattering,

we designed 2 types of EUV light source

<Low Rep. Case (100kHz)>

SC(NC)-RF-Gun and CO2 laser will generate

10 μ W/2%b.w. EUV (6.7nm)

<High Rep. Case (100MHz)>

SC-RF-Gun (or DC-Gun+SC Linac) and CO2 laser with Super-cavity

1mW/2%b.w. EUV (6.7nm) under R&Ds